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MACHINE LEARNING METHODS UTILIZATION IN BUSINESS INTELLIGENCE SYSTEMS

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INFORMAATIOTEKNOLOGIAN TIEDEKUNTA
2023

ABSTRACT

Jaara, Akseli
Machine Learning Methods Utilization in Business Intelligence Systems
Jyväskylä: University of Jyväskylä, 2023, 27 pp.
Information Systems Sciences, Bachelor's Thesis
Supervisor(s): Marttiin, Pentti

This literature review discusses utilization of machine learning methods in business intelligence systems on the viewpoint of benefits of business intelligence systems. Machine learning and the algorithms themselves are continuously evolving way of processing massive amounts of data in order to either produce descriptions or predictions based on available datasets. These algorithms have more and more real-life implementations, and one of those implementations is the business intelligence system improvement, and this thesis focuses on these implementations of the beneficial viewpoint of business intelligence systems. One of the most important findings of this research based on available literature is the mapping of the current utilization of machine learning methods on business intelligence systems' benefits. Especially predictive methods have been studied and developed efficiently; however, the descriptive models and their utilization has been studied very little regarding to the vast amount of possibilities of descriptive machine learning methods on data-driven business development.

Keywords: machine learning, business intelligence, business intelligence benefits

TIIVISTELMÄ

Jaara, Akseli
Koneoppimisen hyödyntäminen liiketoimintatiedossa
Jyväskylä: Jyväskylän yliopisto, 2023, 27 s.
Tietojärjestelmätiede, Kandidaatin tutkielma
Ohjaaja(t): Marttiin, Pentti

Tässä kirjallisuuskatsauksessa käsitellään koneoppimisen hyödyntämistä BI-järjestelmien hyötyjen edistämisen näkökulmasta. Koneoppiminen ja sen algoritmit ovat alati kehittyvä tapa käsitellä suuria määriä dataa tavoitteenaan joko kuvailla käytettyä aineistoa tai tehdä päätelmiä tulevaisuuteen sen pohjalta. Näille metodeille kehitetään jatkuvasti uusia käytännön sovelluksia reaalimaailman ilmiöiden tarkastelemiseksi. Yksi koneoppimisen käyttökohteista on liiketoimintadatan hyödyntäminen, ja tämä tutkielma keskittyy koneoppimismallien hyödyntämiseen juuri BI-järjestelmien hyötyjen kehittämisen näkökulmasta. Yksi tärkeimmistä löydöistä tässä tutkimuksessa on saatavilla olevan aineiston perusteella koneoppimismallien tämänhetkisen hyödyntämisen kartoittaminen lähdeaineistossa esiintyvien BI-järjestelmien hyötyjen suhteen. Erityisesti ennustavia malleja hyödynnetään ja niiden käyttöä kehitetään BI:ssä tehokkaasti, mutta kuvailevia malleja ja niiden hyödyntämistä on tutkittu vähän ottaen huomioon kuvailevien koneoppimismallien hyödyntämisen potentiaalin dataohjautuvassa liiketoiminnan kehittämisessä.

Asiasanat: koneoppiminen, liiketoimintatieto, liiketoimintatiedon hyödyt

FIGURES

TABLES

TABLE OF CONTENTS

1 INTRODUCTION

As artificial intelligence among its subcategories such as machine learning and deep learning has undergone a great shift of popularity on software development and science, utilization of the said technologies have become emerging topic of software development and scientific research. As the popularity of methods on data processing and other applications of artificial intelligence is on the rise, it is relevant to further research the possibilities on further improving the methods of utilizing business relevant data and information. This has of course been a topic in terms of big data and data mining, which often overlap with the key elements of machine learning methods.

This thesis analyses the utilization of machine learning on the domain of business intelligence benefits, and how machine learning methods are being used in increasing machine learning benefits. This thesis further compares the possibilities of machine learning method usage on business intelligence by the limitations of both machine learning methods and business intelligence architecture regarding to available data. The aim is to find the possible areas on business intelligence, and it's benefits to further utilize machine learning in to, in order to business intelligence developers to better utilize machine learning into future solutions. Even though machine learning is utilized at some level on business intelligence solutions, there remains great number of possibilities that have not yet been taken advantage of. Potential outcome of this study is to discover those possibilities. It is certain that there is a great potential for machine learning utilization in business intelligence – but not yet means or best practises to do so.

This thesis combines literature about the subjects and presents similarities and differences between the results. Thesis aims to discuss the subjects between the findings to produce credible conclusions to answer the research question. The research question state as follows:

- How are machine learning methods utilized in improving business intelligence benefits?

This study was conducted as a literature review. The literature used in this study was chosen mainly from known and trusted journals of the field, along with other credible sources. As both machine learning and business intelligence have been studied for decades and the definition and technologies in business intelligence develop rapidly, in addition to definitions of said subjects one of the criteria of choosing literature was recent publication of the article, paper, or book. This was to form as trustworthy and up-to-date study and its conclusions as possible. Libraries used in this study were Scopus, IEEE Xplore, ScienceDirect, Jykdok and Google Scholar. All the literature acquired from the used sources were thoroughly screened for publications, peer review and their used sources. The most fundamental and noteworthy conclusions were based on multiple credible sources. The keywords used on the searches contained "machine learning" and "business intelligence" used both together and separately. Also "business analytics" and "decision support systems" were used in some of the searches due to the close nature of the topics with the business intelligence domain. Similarly, as machine learning methods have been used in big data and data mining solutions, some searches were committed combining aforementioned terms with "business intelligence".

The combination of these keywords provided a great number of credible sources, which also lead to other relevant keywords such as "business intelligence architecture" in the business intelligence context. This turned out to be relevant in the search for literature on machine learning methods used in business intelligence context. As the context of business intelligence is relevant for business decision making, the aim for search or machine learning usage in similar domains were to find literature strictly in business domain, although some of the sources were proven to be useful in other topics such as "big data". This is justified, since large enterprise data in business intelligence is considered "big data". The selection of the literature was done according to the Okoli and Schabram (2010) instructions on literature review process.

The thesis is written in four separate content chapters with following structure: Introduction, Machine learning, Business intelligence, Machine learning methods in business intelligence and Conclusion. First content chapter "Machine learning" describes the definition of machine learning and the distinctions between different machine learning methods. The first chapter also discusses about the relations between artificial intelligence, machine learning and deep learning, following the further description of models and distinction of descriptive and predictive algorithms. Second content chapter "Business intelligence" describes and discusses the definitions of business intelligence following with overview on business intelligence architecture and reasons and benefits for business intelligence systems, as well as goals and benefits of using one. Third content chapter discusses the usage of machine learning methods in improving business intelligence benefits following with further analysis on both descriptive and predictive machine learning algorithms used on improving business intelligence benefits. Fourth content chapter presents the conclusions of this study and views on directions of further studies on the subject.

2 MACHINE LEARNING

This chapter describes the definition and basic concept of machine learning as well as existing machine learning methods based on the literature used on this study. Definition of machine learning is described in chapter 2.1. Due to overlapping use of artificial intelligence, machine learning and deep learning, the relation between the concepts are reviewed in chapter 2.2. Chapter 2.3. addresses the machine learning methods, and chapter 2.4 discusses the key differences and fundamentals of descriptive and predictive machine learning methods.

For the scope of this literature review is limited to machine learning in the context of business intelligence, there is no further explanation about the subject of artificial intelligence itself in the chapter 2.2. The methods are described and reviewed on the scope needed for the domain of business intelligence.

2.1 Definition of machine learning

The history of machine learning dates back to 1960's, when several groups were designing, and testing learning recognition systems based on early work of psychologist Frank Rosenblatt (Fradkov, 2020). In one of the earliest reports of successful trials of machine learning, in his paper Samuel (1959) discusses about the "process of learning" in machine learning algorithms. It has been under debate whether or not it is suitable to use the phrase "learning". As Brethenoux (2020) describes, "It is important to note that machines do not "learn," they store and compute". Also, Ayodele (2010) states that many of the machine learning algorithms "barely resemble how human mind approach a learning task".

According to Alpaydin (2020) machine learning is defined as "programming computers to optimize a performance criterion using example data or past experience". The goal is to form mathematical models, which enables further generation of conclusions and predictions. Alpaydin further continues to divide machine learning models into two distinctive categories, predictive and descriptive. Predictive models are models that help make predictions about future based

on past data, and descriptive models are models that help gain knowledge from data. According to Alpaydin (2020) model can also be both.

2.2 Artificial intelligence, machine learning and deep learning

As in machine learning, also artificial intelligence is a term that stirs up discussion about meaning of intelligence in the concept of software; the term itself is also widely used in many ways (also in the literature reviewed for this thesis), so it is justified to clarify the definition of the term itself: Artificial intelligence is an umbrella term for different kind of artificial intelligence solutions, such as machine learning. Furthermore, machine learning is an umbrella term for different kind of machine learning solutions. On recent decades researchers have been building bigger and bigger models with multiple different layers to solve more complex problems, which is called deep learning (Bonaccorso, 2017) and is one of the more advanced implementations of machine learning. Machine learning is further possible to classify into predictive and descriptive models (Alpaydin, 2020), or into subcategories based on the algorithms they use. This classification is further introduced in the chapter 2.3 "Machine learning methods". Machine learning positions into artificial intelligence as stated in the Figure 1:

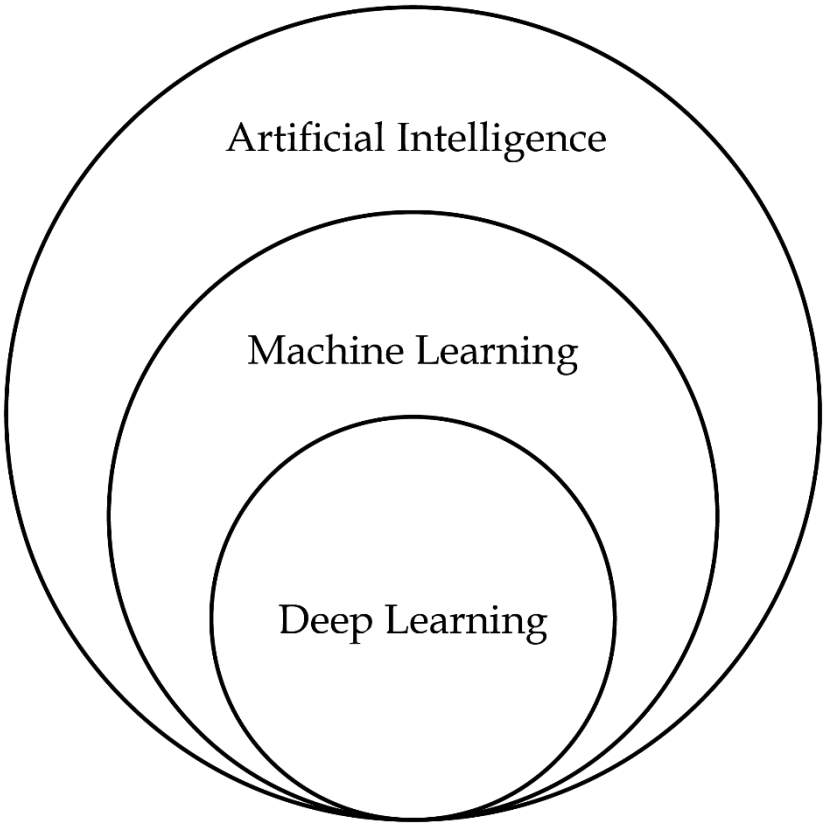

Figure 1. Artificial intelligence hierarchy.

For this thesis aims to produce conclusions of machine learning utilization on business intelligence solutions, it is notable to clarify that the scope of this thesis is narrowed into machine learning methods used in business intelligence solutions.

2.3 Machine learning methods

As previously mentioned, machine learning methods can be categorized into predictive and descriptive methods based on the outcome value of the algorithm (Alpaydin, 2020). Furthermore, methods can be categorised by the way how data is being provided to the algorithm. By that, machine learning methods are dividable into four different categories:

- supervised learning,
- unsupervised learning,
- semi-supervised learning,
- and reinforcement learning.

Ayodele (2010) also mentions transduction and learning to learn. According to Ayodele, transduction is similar to supervised learning, but instead of generating a function, aims to predict new outputs. Furthermore, learning to learn is a set of machine learning algorithms that benefit from not only with experience from training data but also a volume of tasks to train the algorithm that "learns to learn" (Thrun, 1996). Since those are implementations of previously mentioned methods of machine learning, they are not discussed further here.

Selection of the model to be used to perform wanted task is primarily based on two factors: the use case and the amount of available data. In addition to previously mentioned factors, model selection should not be only based on how it fits the particular set of data, but also the model complexity should be taken into consideration. (Myung, 2000)

2.3.1 Supervised learning

When observing the available dataset for the machine learning algorithm to use and it is clear that the data set can be labelled, it is possible to use supervised learning. In supervised learning, the output itself is supervised and the results of the machine learning algorithm are compared to the desired output; as Alpaydin (2016) states, "learning corresponds to adjusting the parameters so that the model makes the most accurate predictions of the data".

Supervised learning is a form of machine learning where the algorithm aims to learn a mapping between a set of input and output variables and applying those into predicting outputs of unseen data (Cunningham, Cord and Delany, 2008). In classification problems, supervised learning is commonly used method

because the goal being to make the algorithm learn a classification system that has been already created (Ayodele, 2010).

2.3.2 Unsupervised learning

Unsupervised learning is needed when available data set has no available labelling to use, and therefore it is not possible to set predefined output classes; as the output is unknown, the main goal of using unsupervised learning is to find out consistencies that the model provides. Ayodele (2010) categorises unsupervised learning by approach of building the model. In first approach mentioned, by giving the model some kind of reward system to indicate whether the model is succeeding or not, and in second, by not "maximising utility function but to find similarities in the training data" (Ayodele, 2010). This is how by unsupervised learning it is possible to find previously undetected structures from the training data.

2.3.3 Semi-supervised learning

When volume of the labelled data available is scarce and the volume itself is not enough to be utilized by supervised learning, it is possible to use semi-supervised learning. In semi-supervised learning when enough data is available in general, it is possible to combine labelled data to unlabelled data to reach the needed volume of data to achieve credible results. According to Zhu (2009) most semi-supervised learning strategies are designed to extend either supervised or unsupervised learning to generate additional information that would be typical for either of the previously mentioned learning strategies. As labelled and unlabelled data is combined, semi-supervised learning relies greatly on the assumption that the similar data points on both labelled and unlabelled data points are likely to belong to the same target class. (Er, Kashyap and Wang, 2016).

2.3.4 Reinforcement learning

Reinforcement learning is a machine learning type that is recommended to use when the desired outcome of the model is not available, but it is possible to set example criterion to determine the success of the performance. The goal itself is not to predict the values of the outcome of the machine learning model, but to achieve the outcome that provides the best result regarding to the criterion set for the success of the model. Barto & Dietterich (2004) states that when algorithm finds a similar result that has been previously found, the maximal potential result is searched from the proximity of the area of the last known maximal result. It is noteworthy to mention, that this leads to a conflict between exploration and exploitation, (Barto & Dietterich, 2004). This means that the algorithm has to balance between exploiting what is already learned, but also explore to learn more to work even more efficiently.

2.4 Descriptive and predictive machine learning methods

The machine learning categorisations were discussed previously from the data processing viewpoint. However, as in this thesis the aim is to review machine learning methods in business intelligence, it is relevant to discuss the machine learning methods from the viewpoint of the goal of the algorithm – what it is developed to perform. As for this distinction, as it has been described previously, all these machine learning algorithms can be divided into descriptive and predictive machine learning models based on the preferred outcome of the algorithm. This has also congruences in business intelligence related topics, and predictive machine learning models are often referred as "predictive analytics" in literature and in public discussion. However, predictive analytics does not necessarily mean predictive machine learning models, but predictive machine learning models can be utilized in predictive analytics. As with the development of machine learning models themselves, predictive analytics rely on more advanced statistical methods (Nyce, 2007) such as advanced regression or time-series models. As the name itself describes, predictive models are developed to make predictions of the future based on the data provided to the algorithm (Alpaydin, 2020). Alpaydin further does elaborate, that algorithm does not necessarily need to be either predictive or descriptive but can also be both.

Descriptive algorithms on the other hand are used to gain knowledge from the data available (Alpaydin, 2020). The goal is to utilize machine learning algorithms in order to better understand the data and make informed assumptions about the information provided by the algorithm that could not necessarily be otherwise utilized. For example, clustering algorithms can divide e.g., customers into customer segments based on available customer data for the algorithm. Therefore, the outcome of the algorithm is not predictive, but descriptive with the aim for better understanding of the data via the information provided by the algorithm.

3 BUSINESS INTELLIGENCE

This chapter discusses the definition of business intelligence, business intelligence's relation to big data and knowledge management, and lastly business intelligence architecture. Hence the term itself has no commonly accepted definition, it is justified to discuss the definition of business intelligence in the domain of this study. The term itself is introduced as early as 1958 by H. P. Luhn (Luhn, 1958), it is reasonable to critically review articles defining business intelligence by the year of the publication in order for this study to achieve as meaningful conclusions as possible.

Chapter 3.1 addresses the definition of business intelligence. Since the aim for this thesis is to study machine learning in business intelligence, technological perspective of use cases of machine learning is needed and architecture of business intelligence systems is discussed in chapter 3.2. Lastly, chapter 3.3 discusses about the benefits of using business intelligence system and why it would be beneficial for a business to use one in the first place.

3.1 Definition of business intelligence

Gartner glossary defines business intelligence as an "umbrella term that includes the applications, infrastructure and tools, and best practices that enable access to and analysis of information to improve and optimize decisions and performance" (Gartner, 2021). In fact, some of the source's state that "business intelligence" as a term was coined by Gartner analyst Howard Dressner in 1990's. This is untrue, since first publication that mentions the term is from 1958 by H. P. Luhn which carries the name "A Business Intelligence System" (Luhn, 1958). As business intelligence is a broad term and even after decades of using the phrase, there is no exact consensus of the definition of the expression; on this chapter, the fundamentals of the definition are based on sources.

Even though most of the existing literature that mentions "business intelligence" as a term itself or as a part of a system has been published post 2000's, there exists some literature and research of its predecessor umbrella term, "decision support system". Even as early as 1960's there was a development of many different kind of decision support applications (Ferguson & Jones, 1969). This kind of development with practical value was seen on the field, and according to Watson (2009) "decision support systems" was used to describe applications and systems, and the whole emerging field altogether. Watson also states that "The use of DSS as an umbrella term to cover a wide variety of decision support applications. Today, the BI term is used in the same way". Watson further continues to describe business intelligence as follows:

> Business intelligence (BI) is a broad category of applications, technologies, and processes for gathering, storing, accessing, and analyzing data to help business users make better decisions. (Watson, 2009)

While this definition of business intelligence is broad, Thomsen (2003) also states that not only did business intelligence replace decision support systems as a term, but also replaced and combined executive information and management information systems. As the term covers category of applications, technologies and processes, the broader perspective of business intelligence as a functional asset is needed. Stackowiac et al (2007) describes:

> Business intelligence can be defined as having the right access to the right data or information needed to make the right business decisions at the right time. (Stackowiac et al., 2007)

Based on what Stackowiac et al. (2007) describes as business intelligence, it is not only about gathering information about business activities throughout the available systems for the whole organisation, but also (and more importantly) right access to the right data. This leads to ability to execute right business decisions at the right time – and deduced by that, data and information should be not only accessible but also understandable and in usable form to utilize it. As Lönnqvist and Pirttimäki (2006) describe, business intelligence aids to circulate and control information within the organisation by identifying and processing the information into useful knowledge and intelligence for managerial use. Based on aforementioned descriptions and definitions of business intelligence, we can conclude business intelligence to be a system for gathering and managing right data or information needed to make informed business decisions efficiently.

3.2 Business intelligence systems and architecture

Similarly to the definition of business intelligence, also the definition of business intelligence system is broad. Watson's (2009) description of business intelligence

describes business intelligence from a system point of view, business intelligence being a "category of applications" for different parts of data management throughout the business intelligence systems. As these systems can be divided further into more and more subcategories, for the scope of this thesis the focus is on general division and architecture of business intelligence systems.

As previously stated, business intelligence consists of different components which relate to each other enabling users to make informed decisions based on the available data. From architectural point of view, there exists a vast number of different kinds of frameworks and point of views of modelling business intelligence architecture; for example, Sherman (2014) divides business intelligence architecture into four different sections; information, data, technical and product architecture. However, most of the literature defining business intelligence architecture describes certain parts of business intelligence architecture, such as

- operational and external databases as data sources,
- the "extract, transform, load process",
- a data warehouse,
- tools for data access and analytics (Hočevar and Jaklič, 2009).

However, some of the sources divide tools for data access and analytics into two different sections, "mid-tier servers" and "front-end applications" (Chaudhuri et al, 2011). This is justified from the use-case point of view: even though OLAP-servers, enterprises search engines, data mining methods and reporting servers are tools for data access, they do not necessarily present useful data to the end-user of the system. As seen on the figure below, Chaudhuri et al. (2011) describe examples of front-end applications as search tools, spreadsheets, dashboards, and ad hoc queries.

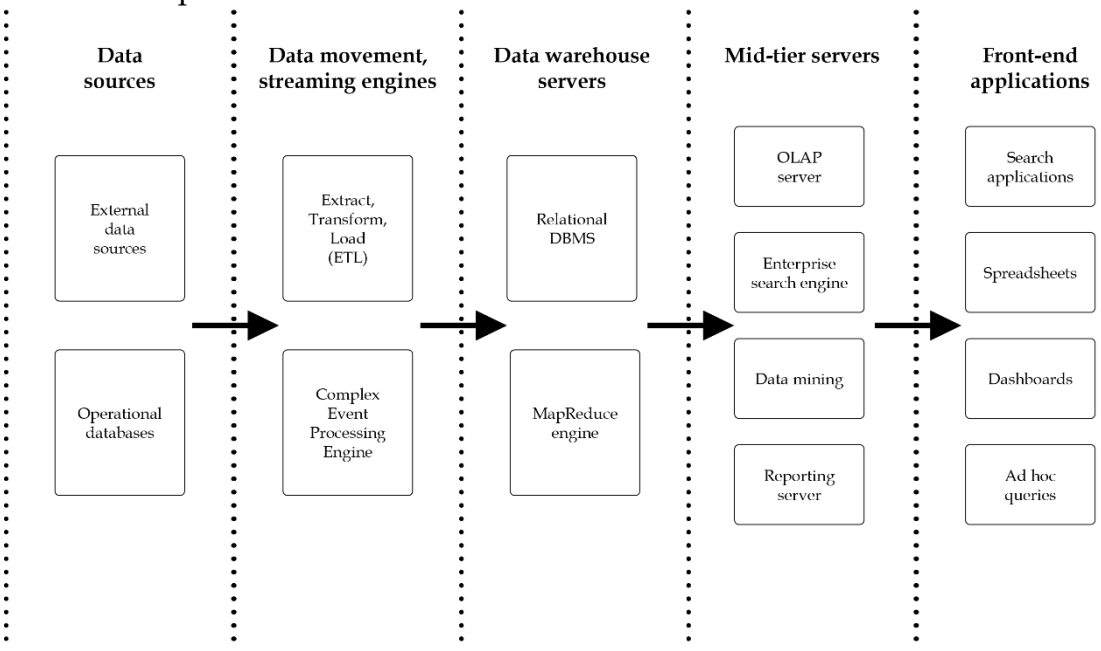

Figure 2. Example of typical architecture of business intelligence system (based on figure by Chaudhuri et al, 2011).

It is noteworthy to say that different variations of the model above on Figure 2 have been defined on literature. On the other hand, much more simplified presentations of business intelligence systems and architecture have been described on literature, as Watson (2009) divides the entity of business intelligence into "getting data in" and "getting data out.

3.3 Objectives and benefits of business intelligence

As with all other investments in business environments, also business intelligence solutions and systems should be justified in one way or another. Mere benefits of the implementation of the system are not enough to justify the investment, and for example, Atre & Moss (2003) presented four components of justification of an investment of information system as follows:

- *Business factors.* Identified business factors, strategic goals of business, and business intelligence application objectives. Implementation of the business intelligence application objectives should support the defined strategic goals of the business.
- *Business analysis issues*. Business analysis issues and needed information to meet the strategic goals should be clearly defined.
- *Cost and benefit analysis*. The estimation of the costs of implementing the system should be done for building and maintaining it. Return of income should be defined by estimation of monetary value of tangible benefits and highlighting the possible positive impact of the organisation's intangible benefits.
- *Risk assessment*. Risks should be assessed not only for financial investment, but also for the technology, complexity, integration, and the project team itself.

Therefore, based on Atre & Moss's (2003) components of business intelligence justification of the system, the goals of implementing one are complex and multiple factors of not only beneficial factors, but also risks and resources should be taken into consideration. As business intelligence systems are seen and used as a support tool that has the ability to support the organisation widely and even on a strategical level, they should have a clear purpose on the organisation itself; as Carver & Ritacco (2006) states, when making decisions about business intelligence investments one of the key criteria is whether the investment itself supports the businesses strategy. This has also been studied on the viewpoint of corporate decision makers, and business intelligence seen as a strategic and operational decision-making support system, Gartner survey ranked the strategic use of business intelligence as follows (Negash, 2004):

- Corporate performance management

- Customer relations optimisation, business activity monitoring and traditional decision support
- Packaged standalone business intelligence applications for specific operations and strategies
- Business intelligence management reporting.

However, it is noteworthy to state that as any other system entities, also business intelligence is evolving and the viewpoints of strategic use of business intelligence systems have and will be changed. As Negash (2004) state, one implication of this ranking could be that great number of companies still see business intelligence as an inward-looking function like its predecessors DSS's and EIS's. To achieve a more updated view of strategical use of today's business intelligence systems, more studies are needed on the subject.

Since a variety of uses cases and justifications of business intelligence systems exist, there is a variety of benefits, and those benefits are company specific based on needs that business intelligence system is acquired for. Therefore, a lot of literature available of the business intelligence systems' benefits define a lot of different aspects of benefits, due to business intelligence system's "soft" nature of many of the benefits (Watson, 2009). However, the bottom line of the benefits stated by the available literature of the topic can be categorised into tangible and intangible benefits. For example, Hocevar & Jacklic (2009) states that business intelligence technology makes it possible for users to rapidly understand complex information and make more efficiently better and faster decisions and thereby efficiently achieve business goals – however, some of the benefits are less directly visible and therefore more difficult to measure.

4 MACHINE LEARNING METHODS IN BUSINESS INTELLIGENCE

This chapter discusses the usage of machine learning methods in business intelligence and aims to systematically discover where in the fields of business intelligence has machine learning been used to improve business intelligence results – and therefore also discover domains where machine learning has not yet been utilized.

Chapter 4.1 discusses the current utilization of machine learning methods on business intelligence mirrored on benefits on business intelligence systems, based on available and reviewed literature about the subject. Chapter 4.2. discusses further descriptive machine learning methods in the context and similarly chapter 4.3. predictive machine learning methods.

4.1 Machine learning methods improving business intelligence benefits

Machine learning models are seen as effective methods in uncovering hidden patterns from available data to create insights from it, and those techniques have been used by data specialists for years (Hlavac & Stefanovic, 2020). As exponential growth of data in business intelligence domain presents new challenges of benefit from it, new alternatives on the data processing methods are needed. As Nashaat et al. (2018) states, research focusing on solutions for big data implementations is becoming essential for industrial applications in the future. Furthermore, Nashaat et al. (2018) continues that as research presents novel solutions utilizing big data in business challenges, most utilize machine learning methods solving those challenges.

As previously discussed, machine learning itself is a wide concept with variety of different kind of tools that can be categorised and used based on the use case and the problem aimed to be solved with it. Similarly, business intelligence as a concept has even various types of meanings based on how business

intelligence itself is viewed – whether it is seen as an information system, process, or a product, and depending on the dimension discussed. As machine learning is a tool that is widely used to improve different kinds of information system functions based on the use case and relevancy, it is relevant to further review available categorised machine learning methods based on business intelligence system function benefit in hand. Simultaneously, as the relevance of machine learning method heavily relies on the use case, it is not relevant to categorise machine learning algorithms themselves on various possible business intelligence functions.

Further, Table 1 categorises machine learning use cases in business intelligence domain found on this literature review. Machine learning methods themselves are categorised into predictive and descriptive machine learning algorithms – of course, the relation of descriptive and predictive analytics used in business intelligence in mind.

Benefit	Descriptive	Predictive
Faster and more accurate reporting		Abedin et al (2020)
Improved decision-making process	Alcabnani et al (2020) Bilal et al (2020)	Dhali et al (2020) Hlavac & Stefanovic (2020) Khan et al (2020) Wach et al (2021)
Improved Customer satisfaction		Khan et al (2020) Lombardi et al (2013)
Improved communication within the company		
Increased revenues		Khan et al (2020) Mariani & Wamba (2020)
Increased profits	He, Xiong & Tsai (2020)	He, Xiong & Tsai (2020) Khan et al (2020)
Increase in market share		Mariani & Wamba (2020)
Savings	He, Xiong & Tsai (2020)	Abedin et al (2020) He, Xiong & Tsai (2020) Khan et al (2020) Lombardi et al (2013)

Table 1. Machine learning methods improving business intelligence benefits.

As can be observed from the table 2 above, surprisingly significant majority of available literature achieved from the queries address predictive algorithms of machine learning methods based on reviewed business intelligence benefit. On many studies reviewed for this table, the predictive qualities of machine learning

algorithms were seen as a progressive turn of business intelligence development, which could be because of the fact that mostly business intelligence solutions in the past have themselves heavily relied on the descriptive business intelligence analytics. Nevertheless, it is noteworthy to state that the absence of literature of descriptive machine learning methods used in enhancing business intelligence systems is something that could be studied further in the future. Not only could predictive models be beneficial for business intelligence implementations, but as Najdawi and Patkuri (2021) state, there lies an immense potential for combining both processed and not processed data with the human interference and intelligence to create more intelligent business decisions.

4.2 Descriptive models in business intelligence improvement

Since business intelligence itself is widely seen as a tool for gathering and analysing existing data in order to improve decision making (among other aforementioned benefits), it is somewhat surprising to discover so little existing literature of improving existing business intelligence methods with machine learning algorithms. This could be due to the previously discussed reasoning of justifying information systems investment with acquired benefit (tangible such as revenue or intangible such as improved decision making), and predictive models have been seen as more interesting means of applying machine learning into business intelligence. However, some literature also addressed descriptive machine learning algorithms, sometimes used alongside predictive models. It is also noteworthy to mention that some of the reviewed literature addressed multiple machine learning models used to solve single problem, which is of course justified based on complexity of the issue in hand. The benefits of using a business intelligence system are listed below along with how the literature justifies using predictive models in order to improve them.

- *Improved decision-making process.* Alcabnani et al. (2020) proposed a model for observing customer satisfaction and reviews from social media using machine learning implementation. Improved decision-making process is justified based on the data extracted via machine learning algorithms used in the solution. Bilal et al. (2020) used several algorithms to profile users' behaviour in order to make conclusions about business reputation.
- *Increased profits.* He, Xiong & Tsai (2020) discusses machine learning approaches to predict churn. Even though the goal is to predict churn, the method includes descriptive machine learning algorithms. The benefit of increased profits is justified based on the fact that cost of attracting new customers is greater than retaining old ones. This of course overlaps with the benefit of savings.

- *Savings.* He, Xiong & Tsai (2020) further discusses benefits on churn predicting with concrete savings due to number of customers that are not lost – since acquiring new ones would be far more expensive.

4.3 Predictive models in business intelligence improvement

As a lot of businesses are dealing with ever increasing amount of available data, new ways of utilizing the data are needed – and are being researched. Predictive machine learning models are one of the most interesting ones due to their nature of being able to make predictions based on past data, one way or another. A fact needed to be kept in mind is that these predictions made by machine learning algorithms are indeed predictions and best guesses made by algorithms, which makes it interesting topic for further research to find out more about finding best practises on predictive machine learning algorithms on business intelligence domains.

As for benefits for business intelligence, found literature covers majority of listed previously on chapter 3.3. and later on, again in Table 1. Most of the literature covers use cases and concepts of different kind of implementations, and some have real-life scenarios completed in cooperation with organisations wanting to utilize machine learning in business intelligence one way or another solving very specific tasks, which could explain the specific need of predictive models. As discussed in chapter 3, business intelligence system investment must be justified based on approximated benefits, it is reasonable to assume that predictions of the future offer more generous return of investment than sole information on past data as in descriptive machine learning models. Nevertheless, even predictive machine learning algorithms had a gap on use cases regarding business intelligence benefits – "improving communication within the company". However, it is debatable whether there is some overlap between "faster and more accurate reporting" and "improving communication within the company", but in this literature review the distinction was made purely on the goal of the implementation of machine learning algorithm, which was in all of the articles the first of the two. Below the benefits of using a business intelligence system are listed and how the literature justifies using predictive machine learning in order to improve them.

- *Faster and more accurate reporting.* Abedin et al. (2020) applied diverse transformation techniques and machine learning methods to overcome issues regarding tax default prediction problems. The study utilized 13 different predictive machine learning algorithms to predict financial statement anomalies and to reduce risk of conspiracy and human error discovering default and fraudulent events.
- *Improved decision-making process.* Dhali et al. (2020) proposes a random forest machine learning model in order to form a predictive model of

customer purchase behaviour. Mentioned benefits for using aforementioned predictive model include significant time savings, and particularly identifying valuable insights of hidden patterns regarding purchase events – and making decisions based on them. Hlavac & Stefanovic (2020) conducted a case study using predictive models in order to forecast employment development. Further, Khan et al. (2020) built demand forecasting model utilizing machine learning for improving decision making process.

- *Improved customer satisfaction.* In addition to improved decision-making process, Khan et al. continues on benefits of implementing machine learning into demand forecasting to benefits on increased customer satisfaction based on businesses better ability to react in advance to increasing demand. Lombardi et al. (2013) discusses the accuracy of classification and its costs in ecommerce applications, and states that more accurate classifications increase customer satisfaction. Similarly, less accurate classification reduces customer satisfaction.
- *Increased revenues.* Similarly, Khan et al. justifies increased revenue benefits with demand forecasting enabling businesses to better answer increasing demand. Mariani & Wamba (2020) concluded that consumer goods companies can utilize advanced machine learning techniques in order to forecast demand and determine market potential for new products.
- *Increased profits.* He, Xiong & Tsai (2020) discusses machine learning approaches to predict churn. The benefit of increased profits is justified based on the fact that cost of attracting new customers is greater than retaining old ones. This of course overlaps with the benefit of savings.
- *Increase in market share.* Mariani & Wamba (2020) further stated that in addition to increased revenues, machine learning can determine market potential for new products.
- *Savings.* In addition to aforementioned benefits, Abedin et al. stated that applying machine learning methods into tax default prediction problems also saves resources such as time and money. Khan et al. adds to benefits of demand forecasting with machine learning the ability reduce costs of supply chain of the business. Lombardi et al. also discusses costs of misclassification of the customer, and with more accurate classification costs can be reduced significantly.

5 CONCLUSION

Machine learning has had significant role in data-heavy operations for some time, but in recent years machine learning has had a new rise as an emerging topic. Machine learning methods have significant impact on improving processes that involve dealing with large amount of data, such as big data applications and of course, business intelligence. As problems vary widely in the domain of data processing, so does different kinds of machine learning algorithms depending on the problem in hand that needs to be solved. While machine learning itself have been used by data scientist for a while, its full potential in business domain is yet to be discovered.

While business intelligence definition as a concept is somewhat different depending on the point of view, there is undeniable benefits for organisations to use business intelligence systems one way or another. As well as business intelligence systems predecessors' decision support systems, a lot of literature reviewed for this thesis saw benefits of utilizing business intelligence solutions mostly on improved ability of decision making. Since business intelligence solutions utilize large amount of organised and unorganised data throughout the systems, there lies a great need of ever developing solutions to further improve the processing of data. This is where machine learning is seen as valuable asset in improving existing processes and creating entirely new ways of creating business intelligence.

Research question for this thesis was "how are machine learning methods utilized in improving business intelligence benefits?" For research and real-life implementations, it is noteworthy to recognise benefits to be improved. Regarding both research and real-life implementations, it is for utmost importance to recognise goals and benefits of business intelligence systems, as they are presented in third chapter of this thesis. These are later on the fourth chapter mirrored on reviewed use cases of machine learning implementation in business intelligence with the type of machine learning method used. Cases with machine learning methods were further analysed with the division between descriptive and predictive algorithms. This was due to the close nature of descriptive and predictive analytics often seen in business intelligence.

Machine learning can significantly improve data heavy processes, also in the domain of business intelligence. The potential of machine learning usage was also seen in the source literature. On the reviewed literature, different kinds of predictive machine learning implementations have been presented for improving machine learning benefits for example in the domain of improving decision making efforts and increasing revenue or profit. A large number of algorithms have been used into forecasting different types of business information, such as sales and churn – however, there were also a gap on predictive algorithms in this context. As source literature states, one of the benefits for business intelligence is to improve communication within the organisation, however, this was not a benefit that had yet been improved by machine learning. This may be due to the fact

that since information systems investments have to be justified in terms of benefits one way or another, improving communication within the organisation is not seen as relevant or profitable. The reasons for the absence of it and possible use cases of machine learning improving communication within the organisation could be a topic for further research.

As business intelligence systems are seen as a tool for improving decision making and analysis on business relevant data, somewhat surprising discovery was that there was not much literature on implementing descriptive machine learning models in business intelligence solutions. As machine learning solutions could improve data management and processing on traditional business intelligence processes, there seems to be a gap of unused potential in these types of implementations. This is also worthy of further research.

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